Problem 3

Part a

The magnitude of the force is

\[ F = |q \vec{v} \times \vec{B}| = qvB \sin \theta \]

Hence,

\[ v = \frac{F}{qB \sin \theta} = \frac{6.50 \times 10^{-17}}{1.60 \times 10^{-19} \times 2.60 \times 10^{-3} \times \sin 23^\circ} = 4.00 \times 10^5 \text{ m/s} \]

Part b

Kinetic energy is

\[ K = \frac{1}{2}mv^2 = \frac{1}{2} \times 1.67 \times 10^{-27} \times (4.00 \times 10^5)^2 = 1.34 \times 10^{-16} \text{ J} = 834 \text{ eV} \]

Problem 9

Accelerating through a potential difference of 1 kV gives the electron a kinetic energy of \( K = qV = 1.6 \times 10^{-19} \times 10^3 = 1.6 \times 10^{-16} \text{ J} \). As \( K = mv^2/2 \), this gives:

\[ v = \sqrt{\frac{2K}{m}} = \sqrt{\frac{2 \times 1.6 \times 10^{-16}}{9.1 \times 10^{-31}}} = 1.88 \times 10^7 \text{ m/s} \]

The magnetic field and the electric field described form a velocity selector arrangement with the selected velocity being \( v = E/B \). Hence, \( B = E/v \). As the electric field between the plates is uniform, \( E = V/d \), where \( V \) is the voltage between the plates and \( d \) is the distance between them. So one gets:

\[ B = \frac{E}{v} = \frac{V}{vd} = \frac{100}{1.88 \times 10^7 \times 0.02} = 2.7 \times 10^{-4} \text{ T} \]

Problem 10

The total electric and magnetic force is:

\[ \vec{F} = q\vec{E} + q\vec{v} \times \vec{B} \]
So,
\[ \vec{E} = \vec{F} - \vec{v} \times \vec{B} \]

From Newton’s second law: \( \vec{F} = m\vec{a} \). Hence,
\[
\vec{E} = \frac{m\vec{a}}{q} \vec{v} \times \vec{B} = \frac{9.1 \times 10^{-31} \times 2 \times 10^{12} \hat{i}}{-1.6 \times 10^{-19}} \times (12 \times 10^3 \hat{j} + 15 \times 10^3 \hat{k}) \times (4 \times 10^{-4} \hat{i}) = -11.4 \hat{i} - 6.0 \hat{j} + 4.8 \hat{k} \text{ N/C}
\]

**Problem 17**

**Part a**

The kinetic energy is \( K = \frac{1}{2}mv^2 \)

So the speed is (remember to convert keV to J)
\[
v = \sqrt{\frac{2K}{m}} = \sqrt{\frac{2 \times 1.20 \times 10^3 \times 1.60 \times 10^{-19}}{9.11 \times 10^{-31}}} = 2.05 \times 10^7 \text{ m/s}
\]

**Part b**

For the circular orbit
\[
\frac{mv^2}{r} = qvB
\]

Hence,
\[
B = \frac{mv}{qr} = \frac{9.11 \times 10^{-31} \times 2.05 \times 10^7}{1.60 \times 10^{-19} \times 0.25} = 4.68 \times 10^{-4} \text{ T}
\]

**Part c**

The angular frequency is
\[
\omega = \frac{v}{r} = \frac{qB}{m}
\]

Frequency is
\[
f = \frac{\omega}{2\pi} = \frac{qB}{2\pi m} = 1.31 \times 10^7 \text{ Hz}
\]

**Part d**

The time period is
\[
T = \frac{1}{f} = 7.65 \times 10^{-8} \text{ s}
\]
Problem 24

The radius of orbit in a uniform magnetic field is \( r = mv/(|q|B) \). Hence,

\[
r_p = \frac{m_pv_p}{q_pB}, \quad r_d = \frac{m_dv_d}{q_dB}, \quad r_\alpha = \frac{m_\alpha v_\alpha}{q_\alpha B}
\]

where the subscripts \( p, d \) and \( \alpha \) are used to denote the corresponding parameters for protons, deuterons and alpha particles. To find the relations between \( r_p, r_d \) and \( r_\alpha \), we first relate all parameters to the corresponding proton parameters. We know

\[
m_d = 2m_p, \quad m_\alpha = 4m_p, \quad q_d = q_p, \quad q_\alpha = 2q_p.
\]

As all particles have the same kinetic energy: \( m_pv_p^2 = m_dv_d^2 = m_\alpha v_\alpha^2 \). Hence,

\[
v_d = \sqrt{\frac{m_p}{m_d}} v_p = \sqrt{\frac{1}{2}} v_p, \quad v_\alpha = \sqrt{\frac{m_p}{m_\alpha}} v_p = \sqrt{\frac{1}{4}} v_p = \frac{v_p}{2}
\]

Putting these results back into the equations for radius of orbits we get:

\[
r_d = \frac{2m_pv_p/\sqrt{2}}{q_pB} = \sqrt{2} \frac{m_pv_p}{q_pB} = \sqrt{2} r_p
\]

and

\[
r_\alpha = \frac{4m_pv_p/2}{2q_\alpha B} = \frac{m_pv_p}{2q_\alpha B} = \frac{r_p}{2}
\]

Problem 33

The force is

\[
\vec{F} = i\vec{L} \times \vec{B}
\]

Using the right-hand-rule gives the direction of \( \vec{F} \) to be east-to-west. The magnitude is

\[
F = iLB\sin \theta = 5000 \times 100 \times 60 \times 10^{-6} \times \sin 70^\circ = 28.2 \text{ N}
\]

Problem 36

The force is

\[
\vec{F} = i\vec{L} \times \vec{B} = 0.50 \times 0.50i \times (0.003\hat{j} + 0.010\hat{k}) = 0.25 \times 0.003\hat{k} + 0.25 \times 0.01(-\hat{j}) = -0.0025\hat{j} + 0.00075\hat{k} \text{ N}
\]
The torque is

\[ \tau = \vec{\mu} \times \vec{B} \]

\( \vec{\mu} \) is in the -z direction. So \( \vec{\tau} \) is in the -y direction. The magnitude of \( \vec{\tau} \) is

\[ \tau = |\vec{\mu} \times \vec{B}| = \mu B \sin 120^\circ = iNAB \sin 120^\circ = 0.10 \times 20 \times 0.1 \times 0.05 \times 0.50 \times \sin 120^\circ = 4.3 \times 10^{-3} \text{ Nm} \]